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BACKGROUND OF THE INVENTION

This invention relates to white-light-generating devices and, more particularly, to devices which generate white light very efficiently.

The "white" color of various fluorescent lamps, for example, as now manufactured is identified by so-called trichromatic coefficients as plotted on the ICI diagram. Such a system for color designation is fully explained in "Handbook of Color Colorimetry" by Arthur C. Hardy, The Technological Press, Massachusetts Institute of Technology (1936). With the use of such a system, the resulting color of a blend or

mixture of two or more light-emitting substances can be readily determined or specified.

The "white" color of various white-emitting lamps as now manufactured can be realized by innumerable spectral energy distributions (known in the art as SED), each of which is selected to provide lumen output and/or color rendition. The white-emitting phosphor which is most used in fluorescent lamps, for example, is known in the art as a "halophosphate" and such a phosphor provides a lumen output which is not as good as desired with a color rendition of illuminated objects which leaves much to be desired.

SUMMARY OF THE INVENTION

It is the general object of the present invention to provide devices which operate to produce "white" light in a very efficient manner.

It is another object to provide devices which produce a mixture of selected "yellow" light and "blue" light in such a manner as to achieve improved efficiency for generating "white" light.

It is a further object to provide devices wherein both blue and yellow radiations are produced by a discharge, or by fluorescent materials (phosphors) excited by the discharge, or by other means, or by a combination of both, in order to generate "white" light in a very efficient manner.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing a device which comprises one or more light-generating media which form an operative part of the device. The device is adapted to be connected to a source of predetermined electric potential in order to energize the light-generating media to a visible-light-generating condition. The visible radiations which are generated substantially comprise a yellow emission located principally within the wavelength

range of from 565 nm to 585 nm and a blue emission concentrated primarily in the wavelength range of from 430 nm to 475 nm. The yellow emission can take the form either of a line-type emission or a narrow band-type emission having a bandwidth of less than about 30 nanometers as measured at an emission intensity which is 50% of the maximum measured intensity for the yellow emission. The relative outputs of the yellow emission and the blue emission are such that when blended together, there is produced white light of predetermined ICI coordinates.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference should be made to the accompanying drawings, wherein:

Figure 1 is an elevational view, partly in section, of a fluorescent discharge device constructed in accordance with the present invention;

Fig. 2 is an x-y chromaticity diagram of the ICI system having imposed thereon various "white" colors;

Fig. 3 is a graph of relative response versus wavelength illustrating the "eye sensitivity" curve;

Fig. 4 is a perspective view, partly broken away, illustrating a solid-state light-generating device constructed in accordance with the present invention; and

Fig. 5 is a perspective view, partly broken away, illustrating an electrodeless discharge device constructed in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With specific reference to the form of the invention illustrated in the drawings, the numeral 10 in Fig. 1 illustrates generally a 40WT12 type fluorescent lamp comprising a tubular vitreous envelope 12 fabricated of soda-lime-silica glass, for example, having mounts 14 sealed into either end thereof, as is customary. Each mount comprises a vitreous portion 16 sealed to the end of the envelope 12 with lead-in

conductors 18 sealed therethrough and supporting at their inwardly extending extremities refractory metal coils 20, which are fabricated of tungsten. These coils are normally of a coiled-coil construction or of a triple-coil construction, and contained within the turns of the inner coil or coils is a filling of electron-emitting material 22.

Electrical connection for the lead-in conductors is effected by contact pins 24 which project from supporting base caps 26 at either end of the lamp. The envelope 12 has coated on its interior surface a finely divided phosphor material 28, which is specially selected in accordance with the present invention. The envelope also contains a small filling of argon or other inert, ionizable gas at a pressure of about 4 mm, for example, in order to facilitate starting, and other starting gas fills at various gas fill pressures may be used, as is well known. Also contained within the envelope is a small charge of mercury 30, as is customary. Briefly summarizing the foregoing lamp 10, it comprises a sealed, elongated, light-transmitting envelope 12 with the electrodes 20 operatively positioned proximate each end of the envelope and adapted to be connected to a source of energizing potential by the lead-in conductors 18 and contact pins 24. The discharge-sustaining filling which is contained within the envelope is the inert, ionizable starting gas and the charge of mercury 30, and the particular device as described is adapted to be operated with a predetermined electric potential to operate with a power input of about 40 watts, in order to sustain a gas discharge therein which generates ultraviolet radiations and some blue radiations. For the particular lamp as described, the blue radiations generated by the discharge constitute about 5% of the total radiations generated by the device, and the ultraviolet radiations generated are primarily the 2537 AU mercury resonant radiations of the low-pressure mercury dis-

charge.

The finely divided phosphor 28, which is coated onto the interior surface of the envelope 12, is specially selected so that when it is excited by the ultraviolet radiations generated by the gas discharge, the phosphor response is primarily a narrow yellow emission which is located principally within the wavelength range of from 565 nm to 585 nm. In this embodiment, the phosphor also emits some blue emission and the total blue emission which is emitted by the lamp 10 when it is operated is concentrated primarily in the wavelength range of from 430 nm to 475 nm. The yellow emission response of the phosphor and the total blue emission from the device, when operated, constitutes substantially the entire visible output of the device, and the relative outputs of yellow emission and total blue emission are such as to produce white light of predetermined ICI coordinates, as explained hereinafter.

In Fig. 2 is shown the x,y-chromaticity diagram of the ICI system and superimposed thereon are color indicia designated "A" through "H" illustrating the color coordinates for present commercial variations of "white" light. Such lamp colors as presently available commercially are designated as follows:

Indicia	Lamp Color
A	warm white
B	deluxe warm white
C	white
D	cool white
E	deluxe cool white
F	soft white
G	bluish white
H	daylight

Reference to the foregoing ICI diagram will show that the term "white" is essentially an arbitrary designation and as a general rule, any x-y color coordinate which is bounded by the dashed line as shown in Fig. 2 will appear white to the eye.

In accordance with the present invention, the total blue emission, which is concentrated primarily in the wavelength range of from 430 to 475 nm, has a purplish blue coloration at the shorter wavelengths and a relatively pure blue coloration at the longer wavelengths within this range. With respect to the yellow emission, at the shorter wavelength range of 565 nm it is somewhat greenish yellow in appearance and at the longer wavelength range of 585 nm it is a somewhat yellowish orange in appearance.

In accordance with the present invention, it has been found that in order to produce "white" light in the most efficient manner, it is necessary to utilize yellowish radiations which fall within a narrow range, and to blend selected blue radiations with these yellowish radiations. As shown in Fig. 3, the yellow radiations as specified fall considerably outside those radiations to which the eye is most sensitive, namely, 555 nm radiations, but if such 555 nm radiations are present in appreciable amounts, and are necessarily complemented by other shorter and longer wavelength radiations to produce "white" light, the overall luminous efficiency of the device will be impaired.

As a specific example for preparing a phosphor mixture in accordance with the present invention, the phosphor coating is formed as a mixture of yellow-emitting dysprosium-activated yttrium vanadate mixed with blue-emitting europium-activated aluminosilicate. The vanadate phosphor exhibits a strong yellow emission located principally within the wavelength range of from 565 nm to 585 nm. The blue-emitting phosphor is described in U.S. Patent No. 3,359,211, dated December 19, 1967. In this specific example, 82 parts, by weight, of the yellow-emitting phosphor are mixed with 18

parts, by weight, of the blue-emitting phosphor in order to produce "white" light of predetermined ICI coordinates of $x = .36$ and $y = .39$. Other phosphors which meet the foregoing requirements can be substituted for the specific example.

In the preferred form of the invention, the yellow emission produced by the phosphor preferably is a line-type emission as is normally obtained through the use of a rare-earth metal activator. If the phosphor has a band emission, however, and the band is sufficiently narrow, such phosphors may also be used to produce fluorescent lamps having good efficiency. In the event the yellow-emitting phosphor has a band emission, the band should be sufficiently narrow that the emission intensity, as measured at 15 nm on either side of its peak, is less than about 50% of the maximum measured emission intensity of the phosphor. The "blue" component is far less critical than the "yellow" component.

As a possible alternative embodiment, the fluorescent lamp 10 as shown in Fig. 1 can be modified in order to change the loading thereon so that the lamp as shown in this figure will be operated with a power input of 100 watts. This will generate a substantial amount of blue radiations having a wavelength of 436 nm. In such an embodiment, the blue-emitting component of the phosphor can be minimized or eliminated since the discharge per se can supply an appreciable portion of, or all of, the blue radiations as needed to produce the "white" output for the device. As a specific example, if the foregoing device as shown in Fig. 1 is to be operated with the power input of 100 watts, the blue-emitting phosphor can be decreased by 12% with respect to the amount as set forth in the fore-

going specific example.

As another modification, the mercury in the discharge-sustaining filling can be replaced by bismuth, which together with the inert, ionizable starting gas will constitute the discharge-sustaining filling. The bismuth discharge will generate ultraviolet radiations together with a strong blue emission at about 472 nm, which emission will comprise the blue component of the lamp emission. This blue emission when combined with the yellow emission from the phosphor, as specified hereinbefore, produces "white" light.

In Fig. 4 is shown a "solid state" type of light-generating device 32 which comprises a combination of junction-type light emitters and electroluminescent-type light emitters. This device comprises conducting electrodes 34 and 36 which bound the junction-type light emitters 38 which as an example are silicon carbide junctions and generate yellow light in accordance with the present invention. The electroluminescent portion of the device is bounded between the electrodes 36 and 40 and the phosphor which is utilized is zinc sulfide activated by copper which is embedded in a dielectric material in conventional fashion. This phosphor emits blue radiations in accordance with the present invention when excited by the electric field which is applied across the electrodes 36 and 40. A light-transmitting cup-shaped member 42, which may be formed of glass, surrounds the light-emitting portions of the combination solid-state junction and electroluminescent device and the member 42 is coated with a light-diffusing coating 44, such as magnesium oxide. In the operation of the device, a DC potential is applied across the electrodes 34 and 36 to cause the silicon carbide junctions to emit a narrow yellow emission, and an AC potential is applied across the electrodes 36 and 40 to cause the electroluminescent phosphor to emit blue radiations. These yellow radiations and blue radiations

are scattered and blended by the magnesium oxide layer 44 in order to produce white light in a very efficient manner, in accordance with the present invention.

As another embodiment, in Fig. 5, is shown an electrodeless discharge device 46 which comprises a sealed, light-transmitting envelope 48 which is charged with a small amount of sodium 50 and bismuth 52. The envelope 48 also encloses a small amount of inert, ionizable gas such as argon. In order to energize the device 46, an RF coil 54, which surrounds the envelope 46, is energized by an RF oscillator in order to partially vaporize the sodium and bismuth. Upon partial vaporization, the sodium emits a characteristic yellow group of lines and the bismuth emits its characteristic blue light, and the combination of yellow and blue radiations produce white light in a very efficient manner. If desired, a phosphor layer 56 formed of europium activated aluminosilicate, as described hereinbefore, can be used to generate the desired blue radiations, either to replace the bismuth or to supplement same. The phosphor is excited by the ultraviolet radiations generated by the sodium discharge.

It will be recognized that the objects of the invention have been achieved by providing devices which produce "white" light in a very efficient manner.

While preferred embodiments have been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A device for efficiently generating white light, said device comprising:

(a) light-generating media forming an operative part of said device;

(b) means for connecting said device to a source of predetermined electric potential to energize said media to a visible-light-generating condition, the visible radiations generated by said media when energized substantially comprising a yellow emission located principally within the wavelength range of from 565 nm to 585 nm and a blue emission concentrated primarily in the wavelength range of from 430 nm to 475 nm,

B said yellow emission and said ~~total~~ blue emission constituting substantially the entire visible output of said device when operated, and the relative outputs of said yellow emission and said blue emission being such as to blend together to produce white light of predetermined ICI coordinates.

2. The device as specified in claim 1, wherein said light-generating media comprises an envelope-enclosed, discharge-sustaining substrate and a phosphor material coated onto the interior surface of said envelope.

3. The device as specified in claim 1, wherein said light-generating media comprise solid-state light emitters.

4. The device as specified in claim 1, wherein said light-generating media comprise an envelope-enclosed, visible-

light-generating, discharge-sustaining substance and a phosphor coated onto said envelope, and an RF coil surrounding said envelope for energizing said discharge-sustaining substance.

5. The device as specified in claim 1, wherein said light-generating media comprise an envelope-enclosed, visible-light-generating, discharge-sustaining substance, and an RF coil surrounding said envelope for energizing said discharge-sustaining substance.

6. The device as specified in claim 5, wherein said discharge-sustaining substance comprises sodium and bismuth.

7. A fluorescent discharge device comprising:

(a) a sealed, elongated, light-transmitting envelope;

(b) electrodes operatively positioned proximate each end of said envelope and adapted to be connected to a source of energizing potential;

(c) a discharge-sustaining filling contained within said envelope, and said device adapted to be operated with a predetermined power input to sustain a gas discharge therein which generates ultraviolet radiations and some blue radiations;

(d) finely divided phosphor material coated onto the interior surface of said envelope, said phosphor when excited by the ultraviolet radiations generated by the gas discharge exhibiting primarily a yellow emission located principally within the wavelength range of from 565 nm to 585 nm, and the total blue emission emitted by said device when operated concentrated primarily in the wavelength range of from 430 nm to 475 nm; and

(e) said yellow emission and said total blue emission constituting substantially the entire visible output of said device when operated, and the relative outputs of said yellow emission and said total blue emission being such as to produce

white light of predetermined ICI coordinates.

8. The device as specified in claim 7, wherein said phosphor comprises a blend of different phosphors.

9. The device as specified in claim 7, wherein said yellow emission produced by said phosphor is a line-type emission.

10. The device as specified in claim 7, wherein said discharge-sustaining filling comprises mercury and inert gas.

11. The device as specified in claim 10, wherein said phosphor is a mixture of 82 parts by weight of europium-activated aluminosilicate and 18 parts by weight of dysprosium-activated yttrium vanadate.

12. The device of claim 1 or 7 wherein said yellow emission is either a line-type emission or a narrow band-type emission having a bandwidth of less than about 30 nm as measured at an emission intensity which is 50% of the maximum measured emission intensity thereof.

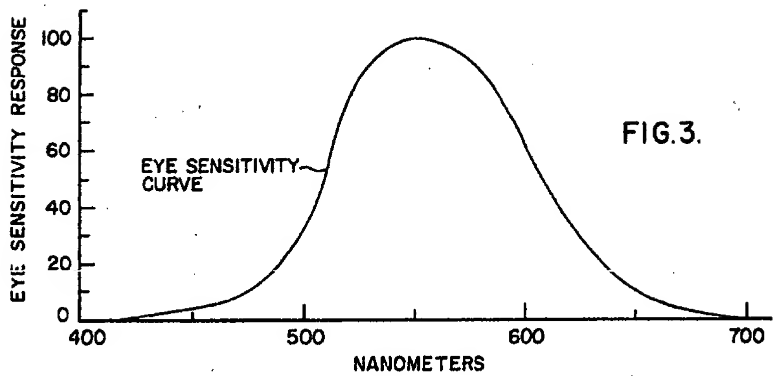


FIG.3.

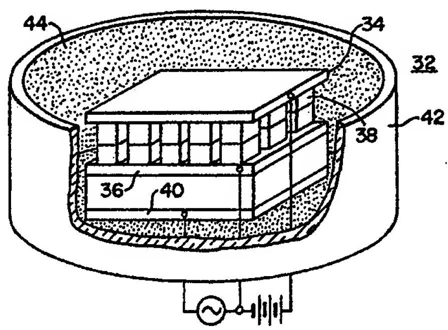
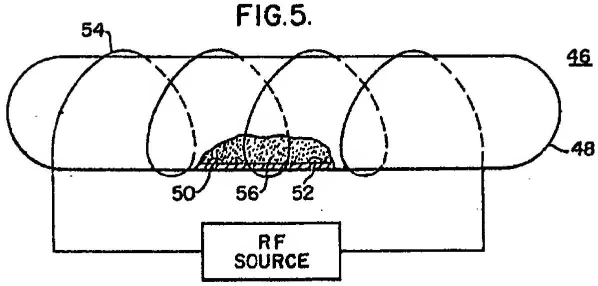


FIG.4.

FIG.5.



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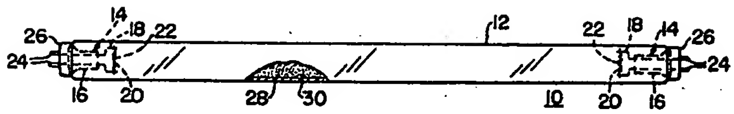

FIG.1.

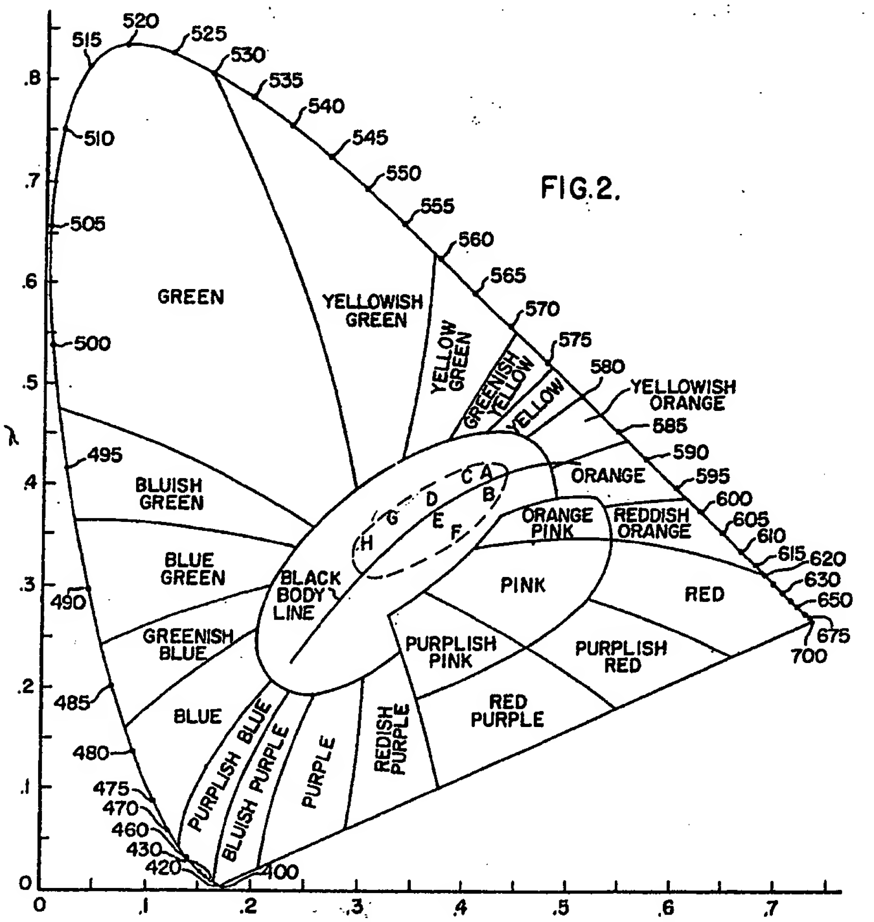

FIG.2.

THE (x,y)—CHROMATICITY DIAGRAM OF THE ICI SYSTEM

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ABSTRACT OF THE DISCLOSURE

Fluorescent discharge or other devices primarily emit radiations concentrated as a narrow yellow emission within the wavelength range of from 565 nm to 585 nm. The devices also generate blue radiations concentrated primarily in the wavelength range of from 430 nm to 475 nm. The relative proportions of blue radiations and yellow radiations are selected to produce white light of predetermined ICI color coordinates.